

was examined end on, so that the radiation probably included rays emitted from the neighbourhood of the negative pole. The whole of the hydrogen had been removed from the Bath gas, but not all the argon. In the spectrum of this gas the rays of helium are dominant, decidedly stronger than those of neon, although the latter are very bright. In the spectrum of the residue of atmospheric air the proportion of helium to neon seems reversed, for in this the yellow neon line is as much more brilliant than the yellow helium line as the latter is the more brilliant in the spectrum of Bath gas. All the prominent lines in the spectrum of the volatile residue of Bath gas were also in that of the residue of atmospheric air except the argon lines. There were, on the other hand, many lines in the latter not traceable in the former, some of them rather conspicuous, such as the ray at about λ 4664. It is, of course, probable that such rays are the outcome of some material not contained in the Bath gas. A very conspicuous pair of lines appears in photographs of the spectrum of the air residue, at about λ 3587, which is not traceable in the spectrum of Bath gas. The helium line, λ 3587.4, is seen in the latter spectrum, but is quite obscured in the former spectrum by the great intensity of the new pair. This helium ray is really a close double, with the less refrangible component much the weaker of the two, but the new pair are wider apart, and of nearly equal intensities; this character also distinguishes them from the strong argon line at λ 3588.6. They are, however, very much more intense at the negative pole than in the capillary, and it will require a good deal more study to determine whether these rays, and many others which we have not tabulated, are due to the peculiarity of the stimulus at the negative pole or to the presence of a previously unrecognised material.

As our mixture of gases probably includes some of all such gases as pervade interplanetary and interstellar space, we early looked in their spectra for the prominent nebular, coronal and auroral rays. Searching the spectrum about λ 5007 no indication of any ray of about that wave-length was visible in the spectrum of any one of the three tubes which had been filled as above described. Turning to the other green nebular line at about λ 4959 we found a weak rather diffuse line to which our first measure assigned a wave-length 4958. The correctness of this wave-length was subsequently verified by measuring with a micrometer eye-piece the distances of the line from the helium lines λ 4922.1 and λ 5015.7 which were in the field of view at the same time. The position of the line was almost identical with that of the iron spark line λ 4957.8, and the conclusion arrived at was that the wave-length was a little less than 4958, and that it could not be the nebular line. There remained the ultra-violet line λ 3727. Our photographs showed a rather strong line very close to the iron spark line λ 3727.8, but slightly more refrangible. As the line is a tolerably strong one it could be photographed with a grating spectrograph along with the iron lines. This was done, and the wave-length deduced from measuring the photograph was 3727.4. This is too large by an amount which considerably exceeds the probable errors of observation, and we are forced to conclude that the nebular material is either absent from our tubes, or does not show itself under the treatment to which it has been subjected.

Although the residual gases of the atmosphere, uncondensed at the temperature of liquid hydrogen, do not show the nebular lines, we found that another tube gave a ray very close indeed to the principal green nebular ray. This tube had been filled with gas prepared in the same way as the others, with the exception that, in passing from the vessel into which the first fraction of liquid air was distilled, it was not passed through a U-tube immersed in liquid hydrogen on its way to the exhausted tube. In consequence it contained traces of nitrogen and argon, and when sparked showed the spectra of these elements as well as those of hydrogen, helium, &c. The nitrogen spectrum disappeared after some sparking, but the tube still showed rays of argon as well as those of the gases in the other tubes. On examining the spectrum of the negative pole in the neighbourhood of the principal nebular green ray, a weak ray was seen in addition to those given by the other tubes. It was found by comparison with the nitrogen rays λ 5002.7 and λ 5005.7 to be a little less refrangible than the latter of these rays, and by measuring its distance from the nitrogen rays and from the two helium rays λ 4922.1 and λ 5015.7 with a micrometer eye-piece, the wave-length λ 5007.7 for the new ray was deduced. This looks as if we might find the substance which is luminous in

nebulae to be really present in the earth's atmosphere, and we hope shortly to be able to verify the observation of it.

Turning to the coronal rays, our tubes emit a weak ray at about λ 5304. This is not far from the wave-length λ 5303.7 assigned by Sir N. Lockyer to the green coronal ray. It is, however, greater than that assigned by Campbell, namely, 5303.26. Other lines observed by us near the places of coronal lines are at wave-lengths about 4687, 4570, 4358, 4323, 4232, 4220, 3985, 3800. These are all weak lines except that at λ 4232, which is of tolerable strength, and that at λ 4220, which is rather a strong line. The wave-lengths 4323, 4232, 4220 and 3800 come very close to those assigned to coronal rays, but the others hardly come within the limits of probable error. The ray 4220 seems too strong in proportion to the others, but the strength of that at 4232 seems to accord with the strength of the corresponding ray in the corona. It will be seen that the rays we enumerate above correspond approximately to the stronger rays in Sir N. Lockyer's list. Further measures of the wave-lengths of the faint lines are needed before we can say definitely whether or no we have in our tubes a substance producing the coronal rays, or some of them.

As to the auroral rays, we have not seen any ray in the spectrum of our tubes near λ 5571.5, the green auroral ray. We have observed two weak rays at λ 4206 and λ 4198, which may possibly, one or both, represent the auroral ray λ 420. The very strong ray of argon, λ 4200.8, would make it probable that argon was the origin of this auroral ray, if the other, equally strong, argon rays in the same region of the spectrum were not absent from the aurora. Nor have we found in the spectrum of our tubes any line with the wave-length 3915, which is that of another strong auroral line. On the other hand it seems probable that the strong auroral line λ 358 may be due to the material which gives us the very remarkable pair of lines at about the place of N of the solar spectrum, λ 3587, which are very strong in the spectrum of the negative pole, but only faint in that of the capillary part of our tubes. It may well be that the auroral discharge is analogous to that about the negative pole. We have also a fairly strong ray at λ 3700, which may be compared to the remaining strong ray observed in the aurora λ 3700. This, however, is a ray which is emitted from the capillary part of our tubes as well as from the negative pole, and is, moreover, emitted by Bath gas, and may very likely be a neon ray.

We hope to pursue the investigation of this interesting spectrum, and if possible to sort out the rays which may be ascribed to substances such as neon and those which are due to one or more other substances. The gas from Bath, even if primarily derived from the atmosphere—which is by no means sure—seems to have undergone some sifting which has affected the relative proportions of helium and neon, and a more thorough comparison of its spectrum with that of the residual atmospheric gases may probably lead to some disentanglement of the rays which originate from different materials. The arrangement of the rays in series, if that could be done, would be a step in the same direction.

The table appended to the above paper is not given here, but it consists chiefly of wave-lengths expressed in four figures only.

THE TREATMENT OF LONDON SEWAGE.¹

WHEN, some years since, the raw sewage of London was regularly poured into the river in the neighbourhood of the city, the road detritus and putrescible faecal matter which were delivered in the sewage settled on the river bed and foreshores. The road detritus tended to permanently reduce the depth of the river; while the putrescible matter, arriving faster than it could be removed by the river or could be destroyed by inoffensive bacterial action, accumulated as a deposit on the foreshores and floated in masses of thick scum on the river. It there underwent foul putrefactive changes, rendering the river most offensive to those who navigated it or lived and worked near its banks, and almost intolerable in summer weather, even to those who crossed its bridges. That this result was inevitable will be understood when it is remembered that the sewage consists of the whole of the water-supply and rainfall over the

¹ Abridged from a paper read before the Society of Arts, on December 12, by Prof. Frank Clowes.

metropolitan area which have been charged with varied refuse matters of our streets, our houses, and our manufactories.

The nuisance was removed by taking the sewage fifteen miles below London. Since this was found insufficient, the sewage was subsequently subjected to chemical treatment and sedimentation before it was allowed to flow into the river. The treatment ultimately adopted, and still in vogue, consists in straining or "screening" off the larger solid matters and then mixing the sewage with solutions of lime and sulphate of iron; the chemical precipitate thus produced is then allowed to settle, together with the finer particles in the sewage, by sending the sewage slowly through parallel channels on its way to the river. The settled matter, or "sludge," is sent in tank-scamers to be discharged out at sea beyond the river's mouth; and the fairly clear "effluent" passes constantly into the river from the northern outfall (Beckton or Barking) and the southern outfall (Crossness) in two streams, which jointly deliver over 200,000,000 gallons every twenty-four hours into the river, and which probably constitute the most important tributaries of the lower Thames near London. Since these processes of chemical treatment and sedimentation have been adopted, the foreshores of the river have become clean, the outrageous foulness of the stream has ceased, and those who live on and near the Thames unanimously express their approval of the improvement effected.

It must be remembered, however, that the effluent of the sewage, after it has been freed from visible foul matter, still contains in invisible solution a large amount of putrescible substance, which may, under suitable conditions, lead to serious foulness in the stream. The effluent at present discharged into the river is practically only clarified sewage. As long as putrefactive changes are delayed by low temperature of the river water, and an ample flush of upper river water comes down to dilute this effluent and to carry it rapidly out to sea, no sensible foulness occurs in the main stream. But in summer time, when high temperature hastens putrefactive change and diminishes the amount of oxygen dissolved in the river water, and when the flush of water from the upper river is diminished by drought and by the abstraction of larger volumes of the water by the water companies, the condition of portions of the lower river frequently closely approaches that necessary to cause offence. There can be no doubt that as the volume of sewage effluent increases, and the abstraction of upper river water for water-supply also increases with the increasing population, these portions of the lower river must pass more frequently into a condition bordering upon or actually causing foulness. It is, therefore, prudent to be prepared to adopt without delay a method of treatment of the London sewage which shall meet the requirements of an increasing population, and shall enable the more ample effluent to be discharged into the river in a state of greater purity than is at present secured.

As far back as 1893, the Main Drainage Committee of the County Council, on the advice of their chemist, Mr. Dibdin, started a large scale experiment on the bacterial purification of sewage, the purification being applied to the effluent from chemical treatment and sedimentation. This experimental treatment has been continued by the committee, on my own advice, and has been considerably extended in its scope. The committee also consented to the association of the eminent bacteriologist, Dr. Houston, with me in these experiments during the three years of their progress. The results which have been obtained have been published by the London County Council in the form of a series of reports which I have laid before them from time to time. The general conclusion to which they point is that the settled sewage may be purified to a far greater degree than it is by the present treatment, by encouraging the spontaneous purifying action of the bacteria which are present in the sewage itself. The effluent thus produced, without the intervention of chemicals, remains free from foul putrefaction and is able to support the life of fish; in these and in all other respects it is greatly superior to the effluent which is at present discharged into the river. The minute vegetable organisms, known as bacteria, exist to the average number of 300,000 per drop of sewage. They only require to be placed under suitable conditions in order to effect the rapid and in-offensive resolution of the putrescible matters of the sewage into harmless and inoffensive products.

The general conclusions derived from the experimental bacterial treatment of raw sewage at the out-falls of the London sewage into the Thames are as follows:—

(1) The following results were obtained by treating the raw

sewage bacterially in coke-beds. In the process adopted, the sewage was allowed to flow into large tanks which contained fragments of coke about the size of walnuts. As soon as the level of the liquid had reached the upper surface of the coke-bed, its further inflow was stopped, and it was allowed to remain in contact with the bacteria coke surface for two or three hours. It was then allowed to flow slowly away from the bottom of the coke-bed. This out-flowing liquid constituted the "sewage effluent." After an interval of from three to seven hours, the processes of emptying and filling the coke-bed were repeated with a fresh portion of sewage. The coke-bed was at first filled in this way twice in every twenty-four hours, but later on it was filled three and four times in twenty-four hours.

(2) A considerable purifying action has been effected by the coke-bed. This is produced by the introduction of bacteria from the sewage. The maintenance of the purifying action is due to the presence of bacteria or their enzymes upon the coke surfaces, and to the adequate aëration of these surfaces by frequently exposing them to the oxygen of the air.

(3) The oxygen undergoes absorption by these surfaces, and the aëration of even the lowest portions of a deep coke-bed seems to be satisfactory in the above method of working, since the air present in the interstices of the coke, between two fillings with sewage, usually contains as much as 75 per cent. of the amount of oxygen present in the air.

(4) Raw sewage, which had been deprived of its larger particles by screening it through coarse gratings, lost practically the whole of its suspended matter by remaining in such a coke bacteria bed for two or three hours. It appears that the suspended particles of faecal matter underwent liquefaction by the bacteria, since they did not collect upon the surface of the coke.

(5) The sand and grit and finer mud, arising mainly from the wear of road surfaces, however, were deposited upon the coke surfaces, and gradually reduced the capacity of the coke-bed.

(6) Hair, fibrous matter and woody fibre derived from the wear of wooden street pavements, and particles of chaff and straw mainly derived from the dejecta of horses employed in the street traffic, were also deposited upon the coke surfaces and gradually choked the coke-bed. These substances, which consist mainly of cellulose, are apparently only acted upon by bacteria with extreme slowness under the above conditions. They arrive, however, in a water-logged condition, and rapidly settle down from the sewage if its rate of flow is reduced.

(7) In dealing with the sewage of the metropolis, it seems best to submit the roughly screened raw sewage to a somewhat rapid process of sedimentation, in order to allow these suspended mineral and cellulose matters (5, 6) to subside; and then to pass the sewage direct into the coke-beds. The dissolved matters and the small amount of suspended matters which are still present in the sewage are then readily dealt with by the bacteria of the coke-bed, and no choking of the beds occurs.

(8) The sewage effluent which is thus obtained from the coke-beds is entirely free from offensive odour and remains inoffensive and odourless even after it has been kept for a month at summer heat, either in closed or open vessels. It is clear, except when a turbidity is produced by fine mud particles washed down by heavy rain. Many pond and river fish have been kept in the constantly renewed effluent for a month, and have been found to be perfectly healthy at the end of that period.

(9) The chemical character of this effluent may be briefly indicated by stating that on an average 51·3 per cent. of the dissolved matter of the original sewage, which is oxidisable by permanganate, has been removed by the bacteria, and that the portion which has been removed is evidently the matter which would become rapidly offensive and would rapidly lead to de-aëration of the river water if it were allowed to pass into the river. The above percentage removal (51·3) was effected by coke-beds varying from 4 to 6 feet in depth. A similar bed, 13 feet in depth, has proved more efficient, and has for some time produced a purification of 64 per cent., while an old bed, 6 feet in depth, has given a purification of 86 per cent. A repetition of the treatment of the effluent in a second similar coke-bed has produced an additional purification of 19·3 per cent., giving an average total purification of 70·6 per cent. (See Table I.). It should be noted that the above purification is reckoned on the dissolved impurity of the sewage; the suspended solid matter is not taken into account. No difficulty has been found in maintaining this bacterial purification.

TABLE I.—*Relative Impurity as Estimated by Permanganate.*

Raw sewage deprived of its suspended matter ... }	3.696	Percentage purification calculated on clear raw sewage.
Effluent from chemical treatment ... }	3.070	16.9
Effluent from single bacterial treatment ... }	1.799	51.3
Effluent from double bacterial treatment ... }	1.137	69.2
River water (high-tide) ...	0.550	—
„ „ (low-tide) ...	0.429	—

(10) The bacteriological condition of the effluent corresponds in the main with that of the raw sewage. The total number of bacteria undergoes some reduction in the coke-beds, but the different kinds of bacteria which were present in the sewage are still represented in the effluent.

(11) The introduction of such a sewage effluent into the lower Thames is unobjectionable. The river water at the points where the effluent is discharged is uniformly muddy; it is always brackish and frequently salt to taste, owing to the presence of tidal sea water. It is, therefore, not capable of being used for drinking purposes. The effluent would certainly cause no deposit upon the river bed, and would ordinarily tend to render the muddy river water more clear by mixing with it. No offensive smell would be emitted by the effluent as it is discharged into the river. And, although the effluent contains more organic matter than the river water does, the bacteria which it contains would slowly and inoffensively remove this organic matter from the effluent after it has been introduced into the river. The effluent would be suitable for the maintenance of healthy fish-life.

A PRE-COLUMBIAN SCANDINAVIAN COLONY IN MASSACHUSETTS.

THE evidence in favour of a partial settlement of Massachusetts by Scandinavians is gradually accumulating, and in the current number of the *American Anthropologist* (New Series, vol. ii., p. 550), Mr. Gerard Fowke adduces new observations. He says, few persons living among the evidences of Norse occupancy have ever paid any particular attention to them, taking for granted that they are the work of the earlier generations of English inhabitants of the region. Those who give more than a passing thought to these objects of unknown origin can see at once that many features connected with them not only would have been unsuitable for any of the necessities of the latter people, as they were then compelled to live, but could not have been turned to any practical use when completed. Such a conclusion is followed at once by the inference that they must pertain in some way to the social customs in vogue among the American Indians; but it does not require an extended acquaintance with aboriginal remains to convince an observer of the error of this inference, the two classes of works being entirely different in many of their most distinctive characters.

Peculiar to the valley of the Charles river are the hut-sites excavated in the hillsides with their rows or piles of boulders to afford a resting place or foundation for the walls of the structures; the ditches that extend with practically a water level along the slopes of the hills; the dams that obstruct the river and many of its tributaries on both sides; the artificial islands walled or protected with stones; the stone walls along the margin

of the streams, between high and low tide—none of these has a counterpart in any known works which can be attributed to Indian habits and life. Of very different character are the extensive earthworks in the bottom-lands; the hill-top fortifications of earth and stone; the immense tumuli of earth or stone, or both combined; and the huge flat-topped mounds of the Mississippi valley, erected by the Indian tribes popularly known as “mound-builders.”

Remains of rectangular houses with very thick walls composed of stones and turf have been found of a size sufficient to accommodate several families in the old Scandinavian fashion. The long-houses of the Iroquois and some of the larger houses built

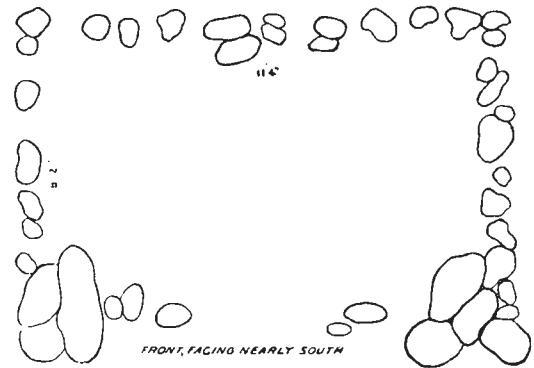


FIG. 1.—House-site above Sibley's, on opposite side of swamp, near Massachusetts Central Railway.

by the Chippewa had the same general form, but with that the resemblance ceases. No foundation was necessary in the Indian house, and it was made principally or entirely of wood and bark. Similarly, nothing at all of Indian origin is known like the cot or hillside huts, of which a number have been examined. These are made by digging back into a sloping surface until a level floor of the desired area is formed; sometimes stones were placed around the sides, in one case (Fig 1) walls of stone and turf were built along the sides. There are indications that such places were covered with timber on which earth was piled.

Near East Watertown is a large natural depression or “kettle-



FIG. 2.—Supposed Norse grave at Clematis Brook, Charles River, Massachusetts.

hole.” Around two-thirds of the circumference of this, artificial terraces have been constructed, apparently to furnish seats from which spectators might view the exercises or ceremonies which presumably took place on the enclosed level area at the bottom. Some what more than a mile south of this “amphi-